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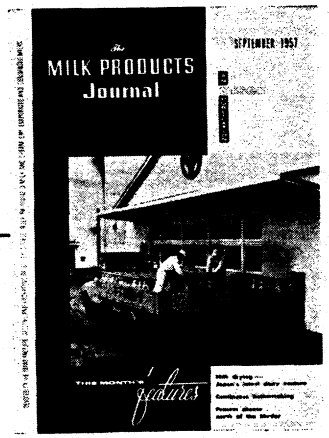

Use of sucrose in the preservation of frozen condensed skimmilk

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TO PRESERVE milk in a frozen state for a long period, it must be heated more than is required in conventional pasteurization[1] and stored at a low temperature[2]. Low heat treatment does not delay the development of an oxidized flavor, while a relatively high storage temperature permits denaturation of the casein to take place at a comparatively rapid rate. The best combination of treatment and storage is limited primarily to dairies which have unusually low (−27° C.) temperature refrigeration facilities. Therefore a method of satisfactory preservation at a more commonly available storage temperature would increase the number of dairies that could preserve milk in a frozen state over a long period.

Condensing pasteurized milk to a 3:1 or higher solids ratio greatly increases its resistance to the development of an oxidized flavor. It is unusual to detect an oxidized flavor in 3:1 milk even when it is stored above −27° C. However, such condensed milks are prone to protein denaturation accompanied by increased viscosity, formation of gel and syneresis.

One of the properties of sucrose is its ability to lower the freezing point of a solution. In milk at a temperature below −0.54° C. it provides more unfrozen water for keeping solids in solution. Leighton and Leviton[3] studied the effect of sucrose in concentrated skimmilks and concluded that its diluting action was the major cause of an increase in fluidity. It was thought that these two effects of sucrose in condensed skimmilk might decrease undesirable changes at frozen storage temperatures above −27° C.

Manufacturing Procedure

Skimmilk was used in the following experiments because interest was focused on the changes that take place in the nonfat portion of milk during frozen storage. It was held in a stainless steel pasteurizer for 30 minutes at 145° F. (62.7° C.), cooled to 130° F. (54.4° C.), drawn into a vacuum pan and condensed to 18.0% solids content. A portion was then withdrawn and condensing resumed. In this way condensed skimmilks that contained 27.0 (3:1), 36.0 (4:1) and 45.0 (5:1) percent, in addition to 18.0 (2:1) percent solids, were obtained. Sucrose was added to these concentrates in such proportions that portions of each contained 5, 10, and 20%. A set of comparable samples was prepared except that the sugar was added to the raw skimmilk.

In a similar manner comparable samples were prepared from skimmilk that was held at 155° F. (68.3° C.) for 30 minutes. The 145° and 155° F. heat treated skimmilks were designated "LH" and "HH," respectively.

Small cans were filled with a sample representing each variable and duplicates of each were stored at −12°, −17°, −22°, and −27° C. From time to time samples were removed from frozen storage and thawed in a water bath at 21° C. The appearance of the samples was noted and viscosity, flavor and sediment were determined.

Results of Experiments

The viscosity of the skimmilks was greater when the sucrose was added before rather than after the pasteurizing and condensing operations. Stebnitz and Sommer[4] studied the age thickening of condensed milks and concluded: "Having the sucrose in contact with the milk during forewarming has the greatest effect in causing the milk to thicken during storage, while having the sucrose in contact with the milk only during condensing at a temperature of 131° F. (55° C.) greatly decreases the viscosity, but makes a more viscous product than adding the sucrose as a syrup near the end of the condensing period." This increase in viscosity was especially noticeable at the 10 and 20% (weight basis) levels. Examples of the pronounced differences in the viscosities of the fresh 5:1 skimmilks are:

(B) Series (sucrose was added before pasteurizing and condensing).

Sucrose (percent)	Viscosity at 21° C. (centipoises)
0	40,000
5	50,000
10	119,000
20	134,000

(A) Series (sucrose was added after condensing).

Sucrose (percent)	Viscosity at 21° C. (centipoises)
0	40,000
5	5,500
10	2,400
20	450

These data show the importance of the time when the sucrose was added.

Since inconveniences and difficulties in handling are encountered when a product becomes highly viscous, studies of the effect of sucrose on the properties of frozen condensed skimmilk were confined to the effects of adding the sucrose after condensing.

Sediment Formation

The extent of the sediment formation in various skimmilks, with and without added sucrose, was compared on an equal (9.0%) milk solids basis with the following results: In 50 ml. of thawed (1:1) skimmilk, with no added sucrose, more than 0.5 ml. (maximum satisfactory limit) of sediment was observed after 150 days at −22° C. or above, while at −27° the sample showed no signs of sedimentation, even after 252 days of storage. The addition of only 5% sucrose to the skimmilk prevented deposition (less than 0.5 ml.) of the proteins regardless of the temperature at which the samples were stored.

In the case of 2:1 skimmilk, undesirable sedimentation was evident after only 36 days at −12° C., while 5% of added sucrose prevented sedimentation even after 120 days at this temperature. The body of the unsweetened samples began to deteriorate at −17° C. within 150 days, while 5% of added sucrose prevented sedimentation during this same storage period. At −22° and at −27° C. all samples remained satisfactory from the standpoint of sedimentation even after 252 days.

Less in Control Samples

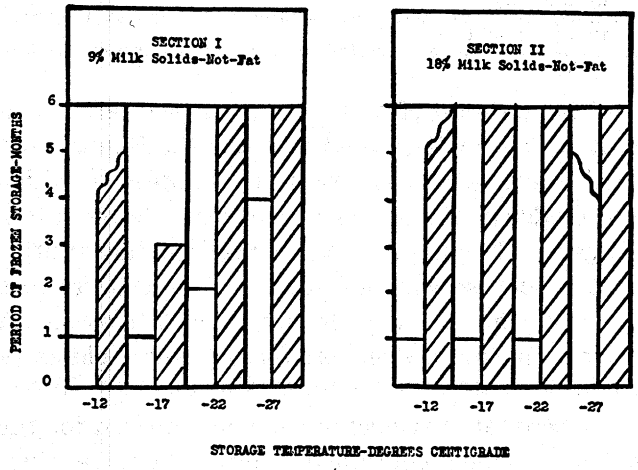
In thawed 3:1 and 4:1 skimmilks there was less deposit, by volume, in the control samples than in the samples to which sucrose was added. This is believed to have been caused by the sucrose forcing the lactose out of solution, since the latter is much less soluble than the former. This deposit formed on centrifuging all samples that were stored at all temperatures. However, it was least noticeable in samples that were stored at −27° C. In 3:1 and 4:1 skimmilks the addition of sucrose for satisfactory storage at temperatures higher than −27° C. may be limited because lactose crystallizes out rather freely in these concentrations and this, in turn, destabilizes the casein.[5] However, upon reconstitution the sediment, largely lactose, readily dissolves. It is more redispersible upon reconstituting than the sediment found in the same milks having no added sucrose.

In regard to the skimmilk forewarming conditions, it was found that the HH (higher heat) treatment was more detrimental to body characteristics than was the LH (lower heat) processing. This is directly opposite to its effect on flavor retention. The amount of sediment formed in the concentrated skimmilks was always greater in the HH samples and this was true whether or not they contained added sucrose. The sediment in samples to which no sucrose was added consisted mainly of curdy, gelatinous particles and of crystalline lactose in excess of its solubility. Those samples having no added sucrose, upon being reconstituted, did not redisperse as completely as samples to which sucrose had been added.

Flavor Evaluations

The flavor was evaluated by a panel of three judges, who tasted the reconstituted samples at monthly intervals to determine when they became unacceptable. The bar graph (figure 1) depicts

Figure I. Monthly interval within which the flavor of frozen condensed skimmilk became unsatisfactory. Solid bars refer to LH, lined bars refer to HH samples.



the effect of the heat treatment on the flavor preservation of the samples. The solid bars represent the LH treatment, while the lined bars represent the period of satisfactory flavor retention of the HH treated samples. The broken bars are designed to show that no more samples were available for further storage observations, while the evenly bisected bars show when the period of satisfactory storage ended.

Although the LH samples developed less sediment at all solids ratios and all storage temperatures, these 1:1 and 2:1 skimmilks developed off flavors (viz. oxidized) more readily than did the HH samples (see bar graph. Sec. I and II). As for the 3:1 and 4:1 concentrates, flavor stability was practically as great in the LH as in the HH samples. Milks of 3:1 (27 percent) solids content or higher normally possess greater resistance to oxidation than those of lower solids content.

TABLE 1

Satisfactory storage temperatures (+)[a] for skimmilks of various solids content without and with the addition of sucrose (45% solids-not-fat milks without and with added sucrose were unstable even when stored at −27° C., and therefore were not included)

Holding temperature (for 30 min.)	Milk solids-nonfat	Sucrose	Storage temperature (° C.) −12	−17	−22	−27	Period of storage
°C.	%	%					Months
62.7	9	0	−[b]	−	−	+	
68.3			−	−	+	+	6
68.3		5	−	−	+	+	
62.7	18	0	−	−	−	+	
68.3			−	−	+	+	6
68.3		5	−	+	+	+	
62.7	27	0	−	−	+	+	
68.3			−	−	−	+	
62.7		5	+	+	+	+	5
68.3			−	+	+	+	
62.7	36	0	−	−	−	+	
68.3			−	−	−	+	
62.7		5	−	+	+	+	4
68.3			−	−	+	+	
62.7		10	±[c]	+	+	+	

[a]Samples stored at these temperatures had good flavor and body stability.
[b]Samples stored at these temperatures had poor flavor or body stability or both.
[c]A border-line temperature for the satisfactory preservation of samples.

The addition of sucrose did not accelerate oxidation. Rather it seemed to make the flavor more easily detectable. For example, samples in which no oxidized flavor was detectable were often judged as having a trace of oxidized flavor after 5% of sucrose was added. These milks were also wheaty (malty), flat or nutty or otherwise off flavor. However, these off flavors were seldom of sufficient intensity to mask the oxidized flavor.

A separate bar graph was not prepared for the samples which contained sucrose because their flavors were not significantly different from those samples which did not contain added sugar.

Discussion and Conclusions

Skimmilks of 9 and 18% solids content, in the preparation of which the fluid skimmilk was held at 62.7° C. for 30 minutes, became oxidized within one month when stored at −12° and at −17° C., while a higher heat treatment (68.3° C., 30 min.) prevented oxidation from taking place in otherwise identical milks for a period of 3 months in the case of 1:1 milks and nearly 6 months in the 2:1 milks. If low solids skimmilk is to be stored in the temperature range of −17° to −12° C., it must be heated more than is required in conventional pasteurization in order to obtain better flavor stability. No off flavor of this type developed in concentrates of higher solids content because 3:1 and 4:1 milks have high resistance to oxidation. Therefore no advantage in flavor retention seems to be had in heating these milks to temperatures that are higher than conventional pasteurization. This was evident in the experiment reported here since both heat treatments produced samples which retained their normal flavor for 6 months or longer when these samples were stored at −12° C. or lower. However, body deterioration was more pronounced in the HH treated samples.

More sediment was observed in samples receiving the higher heat treatment, regardless of the storage temperature or whether sucrose was added or not. However, upon reconstituting, the samples containing sucrose redispersed more readily.

Storage temperatures of −17° and −12° C. were not dependable for satisfactory storage, even though the higher solids milks did not become oxidized, because of poor body stability. However, they were satisfactory at the higher solids levels provided 5 to 10% sucrose was added. A table has been included which gives the combinations of heat treatment, quantity of sucrose added and period of satisfactory preservation at various frozen storage temperatures for various solids skimmilks. While different milks vary in stability these differences are not so great that the table cannot be relied upon in a general way.

It was found that when sucrose was added after rather than before condensing, lower viscosities were obtained which facilitated handling before and after frozen storage.

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